

THE FLIPPIN' MOTORBIKE

A Case Study in Failure Analysis

A study of the chain of events leading to the blowout of a tire in a Benelli 125 cc motorcycle which had been operated for about 2500 miles. Fixation of the cause of the blowout was necessary since the passenger was injured and entered suit against the owner-operator.

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On 17 August 1965, Mr. Daniel Smolak was riding his 1965 Benelli 125 cc motorcycle which weighed about 200 lbs. At that time he was carrying one passenger. Normal tire pressure was 30 psi. On that day, he adjusted the rear tire pressure to 26 psi, leaving the front tire at 30 psi, in keeping with recommended procedure when carrying a passenger. (In the opinion of Dr. Kurt, these conditions were normal for this size tire; 3.00 x 18.) At about 10 a.m., Mr. Smolak had called the attention of the dealer to a crack or blemish about 1/2 in. long on the left side of the rim of the rear wheel.

The motorcycle had been operated only 2500 miles and not under abusive or severe conditions. Mr. Smolak was traveling at approximately 50 mph when he heard a loud bang like a gunshot and immediately the rear wheel of the motorcycle started to whip around. He stated further, "I immediately let off of the gas and applied the rear brake. At this time my passenger fell off the right side of the cycle on the pavement and this threw me off balance." He lost control and was thrown off to the right side after the cycle went into a side-slide on its right side. The cycle came to rest about 100 ft. north of the point where the loud bang was heard.

The right side of the rear wheel is shown in Figure 1 and the left side in Figure 2. Figure 3 shows a closer view of the blowout region of the tire and a separation of part of the rim from the rest of the wheel. The motorcycle dealer commented that this separation in the rim was in the same place as the crack or blemish which had been observed earlier. It was observed that the hole in the inner tube which failed was a simple tear with rubber missing in the shape of an oval, approximately 1/2 in. long, 1/4 in. wide.

Figure 4 shows the tire mounted on the wheel with a new inner tube. After inflation with a hand pump, a "bubble" can be seen in Figure 4. The purpose of this test was to determine whether the inner tube would bulge out between the tire bead and the rim flange where the flange had separated from the rim base or

whether the inner tube would bulge out through the abraded hole in the tire sidewall. At a pressure of 26.5 psi, the tire bead had been forced off the bead seat but the inner tube did not bulge out at that point. Rather, the inner tube was bulging through the hole in the tire sidewall. At a pressure of 42.2 psi, the inner tube was still not bulging out where the bead was off the seat of the rim and the bubble was sticking out of the abraded hole in the sidewall by about 1/2 in. A further increase in pressure by about 5 psi burst the bubble. The appearance of the hole in this inner tube was quite different from that in the accident inner tube. The burst hole was star-shaped with a small piece of rubber (about 1/8 in. diameter) missing at the middle with cracks or tears radiating from this small hole.

Figure 5 shows the wheel with the tire dismounted. The separation of the flange from the rim base is obvious.

Questions:

1. What, in your opinion, caused the "blowout" of the tire leading to the accident and injury of the passenger?
2. Outline, in some detail, what further investigation, if any, you would perform to conclusively determine the cause of failure.



Figure 1

Right Side of Failed Tire Mounted on Rear Wheel



Figure 2

Left (driven) side of failed tire mounted on rear wheel. Note section of rim separated from rest of wheel (at bottom) as well as abraded region on the tire. Note also the deformation of the rim (at the top) in the vicinity of the valve stem.



Figure 3

A Closer View of the Separated Rim and Abraded Portion of the Tire.

A View of the Failed Tire Mounted on the Wheel with a New Tube which has been Inflated. (A "bubble" of the new tube can be seen protruding through the break in the wall.)



Figure 4



Figure 5

Overall View of the Motorcycle Wheel Showing the Left (driven) Side.
(Separation of the rim from the rest of the wheel is obvious. The
arrow in the rim indicates the position of a weld.)

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Visual examination of the area of separation between the rim flange and base suggests a fatigue failure. This is not completely apparent from visual examination since the steel stock was about 49 mils thick and the actual fracture area was partially obscured by rust.

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The wheel was fabricated by forming a strip of steel into the cross-section desired (lips formed by bending the strip, Figure 6) and then, in turn, forming this into a circle and butt welding the ends together. The weld flash was removed, presumably by grinding. Chromium plating was done after all mechanical forming and welding was completed.

Microexamination of the steel shows an annealed ferritic structure with small amounts of spheroidal carbide. The steel was "dead" soft.

A photomicrograph of the cross-section at the weld is shown in Figure 7. This is on the left side of the wheel where the flange separated from the rest of the wheel. Figure 8 shows a cross-section of the weld on the right side of the wheel. Figure 9 shows a section somewhat away from the weld.

Questions:

1. Do you now have enough evidence to reconstruct the chain of events which led to the blowout of the tire?
2. Reconstruct the chain of events, as best you can, and cite the evidence to support your reconstruction.

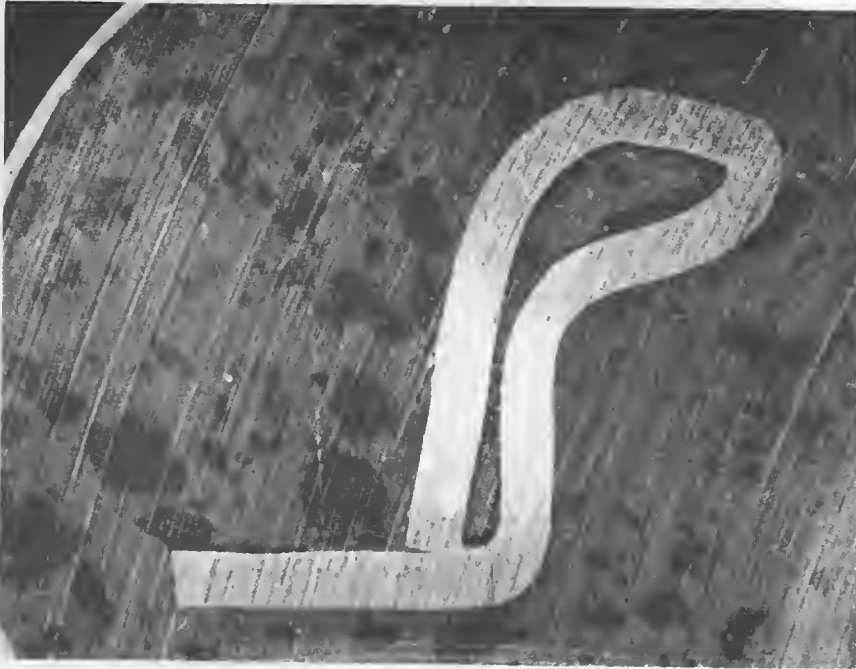
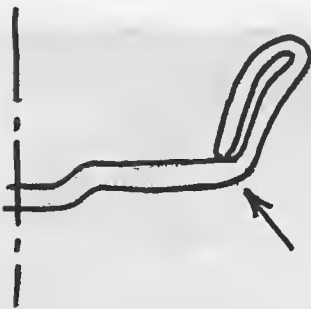


Figure 6

A Section of the Rim Showing the Final Shape after Forming from Steel Strip. Unetched. Magnification: 5X



Looking from Front to
Rear of Motorbike

Cross-section of rim at
weld (left or driven side
of wheel where separation
occurred) showing a crack
in the rim. The thin chro-
mium plate can also be seen.
Etched with 2% nital.
Magnification: 35X

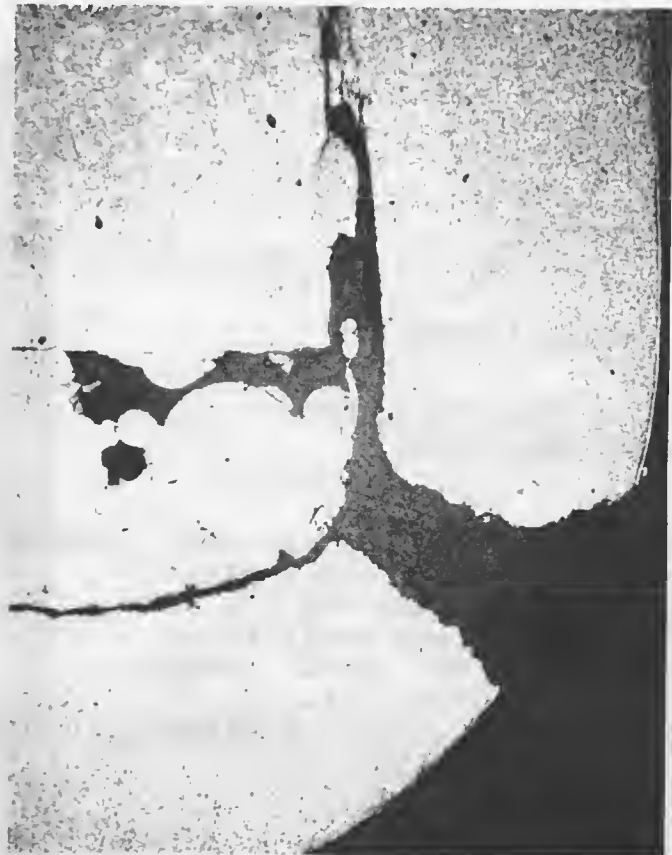
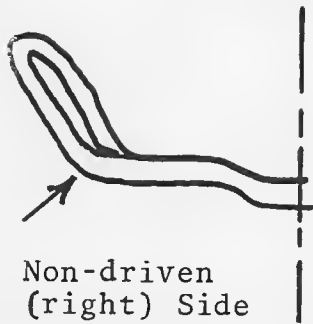


Figure 7



Looking from Front to
Rear of Motorbike

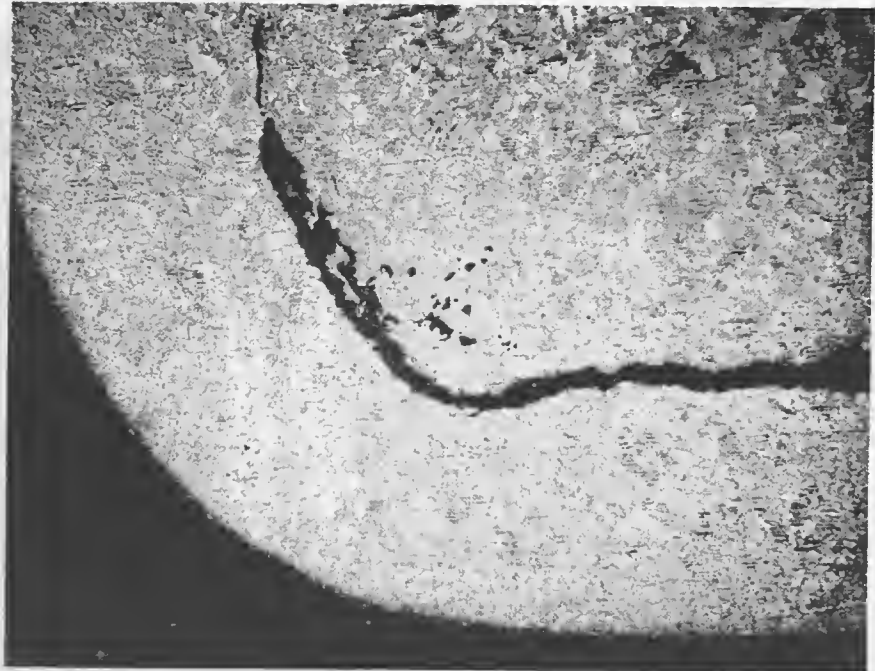
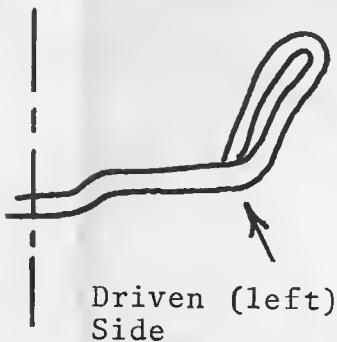


Figure 8

Cross-section of rim at weld (right side, i.e., opposite from Figure 7). There is no evidence of a crack penetration into (or through) the rim. Etched with 2% nital. Magnification: 35X



Looking from Front to
Rear of Motorbike

Cross-section of the rim away from the weld showing a primary crack through the rim with a secondary crack progressing outward from the inside radius. The thin chromium plate is obvious. Etched with 2 % nital. Magnification: 35X



Figure 9

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Reconstruction of events leading to tire blowout

1. Metal failure developed at the base of the rim flange due to fatigue, starting at the poor butt weld and progressing circumferentially because of the thinness of the metal and the sharp inner radius, the latter causing stress concentration at this location. Figure 7 shows weld undercutting and poor weld penetration. In addition, the thickness of the steel from which the rim was formed has been reduced, no doubt by the grinding which was performed to remove the welding flash. Further evidence of poor weld quality and the reduction in thickness is shown in Figure 8. In this case, the thickness has been reduced about 40% from the original 49 mils to about 30 mils.
2. When the metal was sufficiently weakened, the rim flange was bent outward and torn away or separated from the rim base due to the pressure of the air inside the tire against the rim flange and also due to the flexing that occurs near the bead of the tire due to the normal deflection of the tire as it is operated.
3. The bead of the tire was no longer retained in its proper position by the rim flange, but was forced sidewise outwardly where the rim flange no longer contained it.
4. This also permitted the sidewall of the tire to bulge outward, and to rub against some structure on the motorcycle as the wheel rotated, thus abrading through the outer rubber layer and through the two cord plies to form a hole, expose the inner tube, and permit it to bulge out of this abraded hole.
5. The bulged portion of the inner tube was then abraded on the same supporting structure of the motorcycle until it tore, permitting the inner tube to blow out and deflate the tire instantly.
6. The coincidence in location of the separation of the rim flange and the abraded hole in the sidewall of the tire and the hole in the inner tube is significant and is related.
7. Subsequent loss of control, with the accompanying accident and injuries is characteristic of a blown out tire.